GUIDELINES FOR THE APPLICATION OF MUNICIPAL WASTEWATER SLUDGES TO AGRICULTURAL LANDS

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FOREWORD

Guidelines for the application of municipal wastewater sludges to agricultural lands were first published by Alberta Environment in March 1982. The guidelines were intended for the use of municipalities considering or practicing land application as a method of municipal wastewater sludge disposal. After fifteen years since the guidelines were developed, the focus of the program still remains the same, i.e.; land treatment of sludge is agriculturally beneficial and environmentally acceptable.

The first publication in 1982 was prepared by:

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In 1996, Alberta Environment commenced a stakeholder driven process to review and revise the 1982 guidelines. The following participated in the process:

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Chinniah, Karu	-	Alberta Environment
Corkery, Vince	-	City of Edmonton
Hansen, Brent	-	Allegro Environmental
Keyes, Doug	-	Norwest Laboratory
Lang, Pat	-	Alberta Environment
Lutwick, Gerald (chair)	-	Alberta Environment
McEachern, Ken	-	Private Citizen
Pentney, Alan	-	Alberta Environment
Schroter, Allan	-	Private Citizen
Tatem, Ted	-	City of Calgary

Gerald Lutwick, who chaired the stakeholder committee, took the lead role in drafting this document.

It should be noted that these guidelines only apply to the application of municipal wastewater sludge to agricultural lands. The use of sludge for reclamation of marginal or disturbed lands will be assessed on a site-specific basis.

TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 Production and use of biosolids

The primary goal of municipal wastewater treatment is to stabilize nutrients so that, when the treated waste is released to the environment, impact is minimized. Physical, chemical, and biological processes are used to produce a liquid effluent that can be disposed of by irrigation or release into surface drainage courses. The residue that remains is commonly referred to as biosolids (formerly called sewage sludge) and is valued as a soil conditioner and fertilizer.

Biosolid waste is an accumulation of microbial biomass, both living and dead, that results when bacteria use raw sewage as a growth substrate. The waste is primarily of biological origin but also contains metals, nutrients, salts, grit, organic compounds of environmental concern, and pathogenic organisms. The composition of biosolids varies significantly among municipalities and depends on the quantity and quality of domestic, industrial, commercial, and institutional inputs, and on wastewater treatment techniques.

In general, as treatment efficiency increases, the volume of biosolids also increases. Urbanization and more intensive and efficient wastewater treatment systems result in increased production of biosolids. The most common biosolids disposal methods are sanitary landfilling, incineration, permanent lagoon storage, and land treatment. Of these disposal methods, only land treatment offers effective reuse and conservation of valuable biosolids-borne constituents.

1.2 Land treatment as a biosolids disposal option

Land treatment of biosolids is the planned and controlled application of a qualified waste into the soil surface. The intent of land treatment is to use the soil-plant system to degrade, assimilate, and immobilize waste constituents and waste transformational products. The Alberta regulatory expectation of land treatment is maintenance, and preferably enhancement, of the quality of the soil-plant system with minimal risk to human health and other environmental receptors.

A study must be undertaken to assure that land spreading is an environmentally acceptable option for treating a biosolid waste. Elements of such a study include:

1) detailed waste characterization to identify constituents, which preclude or limit land treatment;

2) identification and assessment of site and soil characteristics which impact the treatability of a waste; and

3) integration of information to design a land treatment program that considers application rates, timing, and management and siting requirements.

Where possible, preplanning and design of biosolids characteristics should be considered to enhance acceptability for land treatment. For example, industrial processes and waste streams should be selected, engineered, and managed to preclude the entry of toxic contaminants into a waste intended for land treatment. Municipal wastewater should be treated to reduce volume and water content, stabilize organic matter, and reduce or eliminate offensive odours and pathogens.

1.3 Intent, purpose, and scope of this guideline

This guideline is intended as a resource for municipalities, landowners, and consultants who are involved in developing and implementing programs that use land treatment as a method of municipal wastewater biosolids disposal. Land treatment programs should be developed on the basis of cooperation among waste generators, landowners, and regulators; landowners should not feel obligated to accept biosolids. Potential benefits and limitations associated with spreading biosolids to land are explained in this guideline, and will become better understood with experience. Information is also given regarding contacting Alberta Environment with questions and concerns about program development.

The purpose of this guideline is to ensure that land treatment of biosolids is agriculturally beneficial and environmentally acceptable. The criteria used to describe regulatory expectation are based on experimental data collected by Alberta Environment, on standards and requirements specified in other provinces and countries, and on relevant published technical information. Land treatment of biosolids is an authorized activity as defined in the Alberta Environmental Protection and Enhancement Act; this guideline describes the process of applying for authorization, and explains how information is interpreted to assess the suitability of both a biosolid waste for land treatment and a proposed site to receive such a waste.

This guideline applies only to the application of domestic wastewater biosolids to agricultural lands. Letters of authorization for land treatment of biosolids will be issued only where proposed wastes and receiving sites conform to the philosophy and requirements of this guideline. The use of biosolids for reclamation of marginal or disturbed lands will be assessed on a site-specific basis.

2.0 DEVELOPMENT OF BIOSOLIDS SPREADING PROGRAMS

2.1 Biosolids Characterization

The suitability of biosolids for land spreading depends on the waste stabilization process and the ratios of the macronutrient (nitrogen, N; and phosphorus, P) and trace element (cadmium, Cd; chromium, Cr; copper, Cu; mercury, Hg; nickel, Ni; lead, Pb; and zinc, Zn) contents.

a) Biosolids sampling

The biosolids sample collected should be representative of the quality, in terms of solids content and storage time, of the biosolids that will be spread to land. About 1 litre of biosolids should be collected and stored in a sturdy plastic bottle with a tight fitting lid. A void space should be left at the top of the bottle to provide for accumulation of gases evolving from the biosolids. Freezing the sample is recommended as a way of minimizing microbial activity (and the associated production of gases) during transport to a laboratory.

b) Biosolids analysis

Analyses should include solids content, total nitrogen, ammonium nitrogen, total phosphorus, and total metals (including Cd, Cr, Cu, Hg, Ni, Pb, and Zn). The biosolids should be well homogenized before subsampling for the various analyses.

Analysis for solids content involves transferring 200 to 250 grams wet biosolids into a tared dish and weighing before and after drying in a forced air furnace at 60° C.

Total Kjeldahl nitrogen (TKN; excluding NO_3) is analyzed using a method such as method 3.624, page 129 published by McKeague (1978) or method 22.2, page 203 published by Carter (1993). If the solids content is less than 5 % of the wet sample, then approximately 5 grams (± 0.01 gram) of wet sample is digested; if the solids content is greater than 5 % of the wet sample, then approximately 2 grams (± 0.01 gram) of wet sample is digested. Total nitrogen content should be expressed on a dry weight basis and should be calculated as follows:

$$TKN\ (\%\ of\ dry\ weight) = TKN\ (\%\ wet\ weight) \times \frac{100}{\%\ solids}$$

Ammonium nitrogen is analyzed in wet biosolids using 2 N KCl extraction to displace NH_4^+ from solid particles into aqueous solution. If solids content is less than 5 % of the wet sample, then approximately 25 grams (± 0.01 gram) of wet sample is shaken with 50 mL 2 N KCl. If solids content is greater than 5 % of the wet sample, then approximately 5 grams (± 0.01 gram) of wet sample is shaken with 100 mL 2 N KCl. The extract is collected by filtration and analyzed for NH_4^+ content. The ammonium concentration reported by the laboratory is often expressed in units such as µg NH_4·N/mL of extract and should be converted to µg NH_4·N/g of dry solids (ds) as follows:

for samples with less than 5 % solids:

$$\frac{\mu g\ NH_4\ N}{g\ ds} = \frac{\mu g\ NH_4\ N}{mL\ extract} \times \frac{(50 + (25 - g\ ds))\ mL}{g\ ds}$$

for samples with at least 5 % solids:

$$\frac{\mu g\ NH_4\ N}{g\ ds} = \frac{\mu g\ NH_4\ N}{mL\ extract} \times \frac{(100 + (5 - g\ ds))\ mL}{g\ ds}.$$

Drying biosolids samples to determine solids content assumes that only water is lost; loss of other constituents, such as ammonium, is ignored.

Total phosphorus and metals are analyzed in a strong acid digest of the dried material used for solids content analysis. A 1-gram (± 0.01 gram) portion of dried and finely ground solids is digested, using a method such as EPA 3050 or EPA 3051, and analyzed for P, Cd, Cr, Cu, Hg, Ni, Pb, and Zn. Results should be expressed as µg/g dry solids.

Ratios of nitrogen and phosphorus to metal concentrations should be calculated and included in the analysis report. The Municipal Biosolids Quality Report in Appendix C provides a worksheet for this calculation and comparison to regulatory criteria.

2.2 Site and Soil Characterization

Land treatment site and soil suitability to receive biosolid waste depends on properties that minimize the potential for impacting human or environmental health because of surface erosion or movement of contaminants downward through the soil profile.

a) Site properties

Site characterization should include a measure of the steepness of common slopes, primary direction of surface drainage, depth to the seasonal water table and potable

aquifers, a three-year cropping plan, and area available for biosolids spreading. This information should be compiled onto a sketch map showing proximity to major surface drainage courses, water bodies, publicly used areas, and residential development (a sample sketch map is provided in Appendix C).

b) Soil sampling

The proposed field, usually a quarter section of land, is divided into a suitable number of land units; the total number of land units is usually 4 but could be more if the landscape is complex, or less if a smaller field is being assessed. A land unit should not exceed an area of about 15 ha (40 acres). An ellipse is described in each land unit to enclose about ⅔ of the area of the land unit; soil samples are collected (at least 6 on a relatively flat land unit and up to 10 on a hilly land unit) at equally spaced intervals around the circumference of the ellipse from the 0 to 15 and 15 to 30 cm depths. A composite sample is prepared for each of these two depths. At one of the sampling points in each land unit, soil samples are collected from the 30 to 60 and 60 to 100 cm depths. Thus, at least 16 soil samples are collected from the proposed field (4 depths at each of at least 4 land units). About 1 kilogram of each soil sample is placed in a plastic bag and a label is attached to identify the sample in terms of the land unit and depth from which it was taken. Land units and sampling locations should be identified on a sketch map.

c) Soil analysis

Methods of soil analysis cited here are included in two books: 1) "Manual On Soil Sampling And Methods Of Analysis", edited by J.A. McKeague, and published as the 2nd edition in 1978 by the Canadian Society of Soil Science, and 2) "Soil Sampling and Methods of Analysis", edited by Martin Carter, and published in 1993 by Lewis Publishers (ISBN 0-87371-861-5). Other standard reference books for analytical methods are acceptable provided that the analytical results generated are comparable to those generated using the methods given in the books cited above. Soil properties used to assess the suitability of soil to receive biosolids are pH, particle size distribution, lime requirement for low pH soils, and plant available nitrogen and phosphorus.

i) Soil pH

Soil pH is measured, after 1 hour for equilibration, in a slurry of 10 g soil with 20 mL water (McKeague's method 3.13, page 67; or Carter's method 16.2, page 141). Soil samples containing high organic matter contents might require more water to leave enough clear liquid above the settled solids for pH electrode immersion. Ratios of soil:water of 1:5 or 1:10 are acceptable but should be noted in the analysis report.

ii) Particle size distribution

Analysis of particle size distribution is based on the predictable way in which solid particles settle out of aqueous suspension. The largest particles fall most rapidly and the smallest particles least rapidly so that, at any time, the density of an aqueous soil slurry is a function of the concentration of solid particles remaining in suspension. It is adequate, for the interpretative intentions of this guideline, to use a hydrometer to measure the density of the aqueous soil suspension - at 40 seconds to estimate sand content and at 7 hours to estimate clay content (McKeague's method 2.121, page 15; or Carter's method 47.3, page 507).

Sample preparation to remove carbonates, organic matter, soluble salts, and iron oxides is usually not required. However, clayey soils are rated class 2 and sandy soils class 3 for receiving biosolids, and accurate analysis for some soil samples will be needed. For calcareous or organic soil samples with clay or sand content expected to be greater than 50 %, samples should be treated to remove carbonates and organic matter before analyzing the particle size distribution (McKeague's method 2.111, page 6; or Carter's method 47.2.2, page 503).

Sand, silt, and clay contents should be calculated and the texture class determined using the soil textural triangle adopted by the Canadian Society of Soil Science.

iii) Plant available nitrogen

Many methods are available for estimating plant available nitrogen and each is part of the various fertilizer recommendation procedures used to assess and manage soil fertility status. Differences are often observed among these methods in terms of the reported concentration of plant available nitrogen in a soil sample; for the purpose of this guideline, only the following method is acceptable.

The method of extraction specified here (McKeague's method 4.35, page 165; or Carter's method 4.2, page 26) is selected because it is relatively inexpensive and is conducted by most commercial laboratories. Extracted mineral nitrogen,

especially from biosolids treated soils, is expected to include a significant fraction of nitrogen in the ammonium form. Carter's method is preferred because the higher extraction ratio of 1:10, compared to McKeague's 1:5, should maximize extraction of exchangeable ammonium. Analysis for ammonium and nitrate in the KCl extract can use any analytical method recommended by any of the well known reference manuals (e.g., Association of Official Analytical Chemists, Standard Methods for the Examination of Water and Wastewater, McKeague, Carter, Agronomy 9). Analyze samples from the 0-15, 15-30, 30-60, and 60-100 cm depths, and express results as µg N/g soil. Extractable nitrogen should be calculated and expressed as kg N/ha using the following formula (note that the mineral nitrogen content in the 60-150 cm depth increment uses the nitrogen content in the 60-100 cm sample, and assumes that nitrogen content in the 100-150 cm depth is the same as in the 60-100 cm depth):

$$\frac{kg\,N}{ha} = \frac{\mu g\,N}{g\,soil} \times \frac{A\,g\,soil}{ha} \times \frac{10^{-6}\,kg\,N}{\mu g\,N}$$

where:

$$A = \frac{10^4\,m^2}{ha} \times B\,m \times \frac{C\,g\,soil}{m^3}$$

B = 0.15 *for 0-15 cm depth*
= 0.15 *for 15-30 cm depth*
= 0.30 *for 30-60 cm depth*
= 0.90 *for 60-150 cm depth*

$C = 1.3 \times 10^6$ *for 0-30 cm depth*
$= 1.7 \times 10^6$ *for 30-150 cm depth*
(if soil bulk density is known, insert known value for C)

An estimate of plant available nitrogen is calculated as the sum of extractable nitrogen, in the ammonium and nitrate forms, in the surface 1.5 metres of soil, and should be expressed as kg N/ha.

iv) Plant available phosphorus

Phosphorus is not expected to move downward through the soil profile and is measured to indicate relative value of a field to a biosolids spreading program. If several fields are investigated for suitability to receive biosolids and all other factors are equal, the fields can be ranked in terms of relative value to the program according to phosphorus status. This ranking is always valuable but is probably

most valuable when fields are proposed to receive repeated applications of biosolids (phosphorus from the previous biosolids application should have been removed through cropping or fixed as stable soil minerals before more phosphorus is added with the next biosolids application). Timing and fertilizer management for bringing a field into a biosolids spreading program are more easily planned on the basis of relative value of fields to the program.

Extractable phosphorus should be assessed, in the 0-15 and 15-30 cm depths, using one of the common extractants (for Alberta soils, the Modified Kelowna extracting method is preferred) and a suitable method for analyzing $PO_4 \cdot P$ content in the extract. Alberta Agriculture, Food and Rural Development has published "Phosphorus Fertilizer Application in Crop Production" as Agdex 542-3 (Revised April, 1997); this publication summarizes information pertinent to Alberta about assessing soil phosphorus status. The analytical results should be expressed as µg P/g soil and, if a fertilizer recommendation is included, an estimate should be given of kg P_2O_5/ha needed to support the crop to be grown. The most recent version of the Alberta Fertilizer Guide (published as Agdex 541-1 in the Agdex series by Alberta Agriculture, Food and Rural Development) can be used to assess phosphorus deficiency according to soil zone (Brown, Dark Brown, Thin Black, or Black and Gray Wooded) and cropping intentions.

v) lime requirement

For soils with low pH, lime amendment is required to minimize the plant availability of biosolids-borne metals. Sufficient lime must be added so that pH in the surface 30 cm of amended soil is at least 6.5. The amount of lime required to effect this control can be assessed using laboratory analysis or an empirical technique based on experience with lime addition to acidic Alberta soils.

Laboratory analysis should be conducted on soil samples collected from the 0-15 and 15-30 cm depths for which the pH is less than 6.5. The analysis should be done using Carter's method 14.2, page 110, or equivalent, and calculation should be made of the amount of lime required to increase pH to 6.5. The amount of lime required for soil amendment is the sum of the lime requirement determinations for the soil samples collected from the 0-15 and 15-30 cm depths.

Alberta's Department of Agriculture, Food and Rural Development has monitored lime addition to agricultural soils and has summarized the effect of known additions of lime to soils with various properties. Their observations show that addition of 4.5 tonnes of lime to one hectare of a sandy soil with low organic matter content, or 18 tonnes of lime to one hectare of clayey soil with high organic

matter content will increase soil pH in the surface 30 centimetres by one unit (typically from pH 5.5 to pH 6.5). The following empirical method interpolates between these extremes of lime requirement and gives a weight to organic matter content double that of clay content in terms of controlling the effects of added lime.

Organic matter content factors are derived on the basis of soil colour, and use the conventions adopted by the Canadian Society of Soil Science from the Munsell system of colour notations. The colours of the majority of Alberta soils are described using the 10YR page of the "Munsell Soil Color Charts". The value of the soil colour can be derived from soil survey information, a land location and the "Soil map of Alberta", or as part of a field investigation. If the soil colour value is 7 or greater, then the organic matter content factor is 1. If the value of the soil colour is 4 or less, then the organic matter content factor is 3. Otherwise, the organic matter content factor is 2.

Soil texture should be derived, for a given soil sampling location, on the basis of the average sand and clay contents in the 0-15 and 15-30 cm sampling depths. Soils with a clay content of at least 40 % have a texture factor of 2; soils with a sand content of at least 50 % have a texture factor of 0; otherwise, the texture factor is 1.

The following formula should be used to calculate lime requirement based on the derived factors for organic matter content and texture (lime requirement is expressed as tonnes $CaCO_3$/hectare):

Lime requirement $(t/ha) = (6.5 - pH) \times 2.25(2 \times OMCF + TF)$

where: *pH is measured in water*
OMCF means Organic Matter Content Factor
TF means Texture Factor

Commonly used liming materials include agricultural lime ($CaCO_3$), slaked lime (CaO), and quick lime ($Ca(OH)_2$). Slaked lime and quick lime tend to increase soil pH markedly and could shock soil biota; their use is discouraged except when small amounts of lime are needed to control soil pH (less than 4 t/ha) and other materials are not available. Agricultural lime should be used whenever possible. In excess, it controls soil pH at about 8, but it is sufficient to add only enough lime to bring soil pH to 6.5.

2.3 Land Treatment Program Design

Program design integrates information about biosolids, site, and soil characteristics with available options for biosolids application and restrictions that apply to cropping, application rates, and proximity to land features (Appendix A - Tables 1 to 5).

a) Criteria pertaining to biosolids classification and quality

Biosolids are classified, on the basis of degree of stabilization, into three groups: Digested, Wastewater Lagoon, and Undigested. Digested biosolids are potentially less environmentally hazardous than those from wastewater lagoons. Undigested biosolids pose a greater potential environmental hazard than either digested biosolids or wastewater lagoon biosolids, and should not be used in land spreading programs.

Irrespective of class, all biosolids must meet the minimum acceptable nitrogen or phosphorus to metal ratios listed in Table 1. The intention of these criteria is to discriminate against biosolid wastes that have high metal contents in combination with either low nitrogen or phosphorus contents. Compliance with these biosolids quality criteria ensures that the value of adding the nutrients needed for plant growth is not outweighed by the cost of coincidentally using up some of the soil's capacity to sequester harmful trace metals. Spiking of biosolids with other sources of nitrogen or phosphorus to meet these criteria is not permitted. Biosolids that do not meet these criteria can be upgraded by lowering metal inputs to the treatment system or by employing handling and storage techniques, which conserve nutrients.

b) Criteria pertaining to site and soil classification

Sites proposed for biosolids application have been divided into four classes based on soil pH and texture, slope, and depth to potable aquifers (Table 2). Class 1 sites are the most suitable for biosolids application. Class 2 sites are more suitable than Class 3 sites, and Class 4 sites are not acceptable.

A minimum soil pH, either natural or through amendment, is targeted to promote microbial activity, reduce bioavailability and mobility of potentially harmful chemical species, and promote nutrition. All sites receiving biosolids must have pH of at least 6.5 in the surface 30 cm of soil. Proposed sites not meeting this criterion may be upgraded by liming. Acidic surface soils are precluded from receiving biosolids. Low subsoil pH can not be reliably controlled with surficial lime addition and such land should not be used in a land spreading program; acceptable sites must have an average pH of at least 6.0 in the 30 - 100 cm depth. The minimum pH requirement of 6.5 for

surface soil may be waived if the biosolid waste is derived from a wastewater treatment facility having a lime-based phosphorus removal system, and if waste application will add sufficient lime to control soil pH at 6.5 or greater.

Medium to fine textured soils are preferred. Very fine textured soils (HC and C in Table 2) are downgraded because they are more susceptible to surface erosion with heavy rainfall and subsequent contamination of surface water. The application rate for sandy soils (SL and LS in Table 2) is reduced because of the potential for mineral nitrogen movement downward through the soil profile and subsequent contamination of groundwater systems. Very coarse soils are precluded from use in a land treatment program.

Biosolids application to land is restricted to those fields with slopes less than 9%; environmentally innocuous biosolids could be exempted to allow for applications such as revegetation to control erosion in areas with steeper slopes. Closed drainages are preferred to open drainages. Sites with a seasonal water table within 1 m of the soil surface, and areas underlain by a shallow potable aquifer, should be avoided.

c) Criteria pertaining to biosolids application rates

Table 3 summarizes allowable application rates based on biosolids properties (degree of stabilization, and solids and nitrogen contents). Assuming no limitations because of biosolids, site, or soil properties, digested biosolids can be applied at a rate of 25 tonnes dry biosolids /hectare of land. Application rates are reduced because of lower degrees of waste stabilization; high biosolids contents of nitrogen, phosphorus, or metals; coarse or fine soil textures; shallow depth to a potable aquifer; and high slopes.

Table 4 lists the amount of some biosolids-borne elements, which may be applied cumulatively and in a single application. Maximum cumulative additions decrease as site suitability decreases. Single application event maxima are one-third of the maximum cumulative additions.

Total nitrogen application with biosolids spread to land can be as much as 900 kg N/ha, up to half of which can be in plant available nitrogen forms. Because of the potential for nitrogen movement downward through the soil profile, biosolid wastes must not be applied to land which has more than 250 kg mineral nitrogen/hectare (220 lb mineral nitrogen/acre) in the surface 1.5 m of soil (mineral nitrogen means nitrogen in the ammonium and nitrate forms). It is recommended that the first commercial fertilizer addition to a parcel of land following biosolids application be based on soil fertility test results.

d) Additional application restrictions (Table 5)

Land treatment of biosolids is generally restricted to relatively dry and frost free soil conditions. Land treatment of environmentally innocuous wastes outside these restrictions (for example, lime to control soil pH) might require documentation in support of minimal soil damage and environmental impact.

Acceptable methods of biosolids application are direct injection and surface application followed, within 1 day, by incorporation (tillage). Direct injection is preferred because it reduces the chance for runoff contamination, the potential for odour and aesthetic problems, and evaporative losses of nutrients, particularly ammonium nitrogen.

Minimum distances from a number of environmentally or socially sensitive features must be accommodated in land spreading programs. Municipalities and haulage contractors are advised that it may often be in their best interests to exceed the buffer distances listed in Table 5; they should not be interpreted as maximum distances.

Spreading biosolids to land is restricted to a time of the year when conditions will permit injection or surface spreading/incorporation. Because of the potential for surface water contamination, application to ice-covered, snow-covered, or frozen soils is not permitted unless immediate incorporation is possible.

The potential for damage to buried pipelines, because of the high frequency of crossings during land spreading of biosolids, is a concern. Alberta Environment recommends that biosolids haulers seek the approval of pipeline owners before crossing onto target fields.

Biosolids application is restricted to lands intended for the production of forages, oil seeds, small grains, dried legumes (peas, beans, etc.), trees, and commercial sod. Direct grazing of crops in biosolids-treated fields is not recommended for a period of three years following application because of concerns related to nitrate content of the crops and transfer of pathogens. The greatest dangers, with respect to excess nitrate content of plants, exist in the first crop immediately following application, in newly-emerging plant tissue and in hail-damaged, immature cereal crops, especially oats. Therefore, after biosolids application, grains such as wheat and barley should be grown earlier, and oats later, in the crop rotation. Biosolids should not be applied to lands that may be grazed by dairy cattle or used to grow root crops or crops that may be eaten raw. Cropping practices that are not recommended on biosolids amended land include production of root crops, tobacco, crops eaten raw, or use in dairy farm pasturing; biosolids should not be applied to fields intended for these uses.

3.0 EQUIPMENT CALIBRATION FOR APPLICATION OF BIOSOLIDS

Alberta Environment, through the Letter of Authorization for land application of biosolids, specifies the maximum amount of biosolid waste, which can be applied to land. Criteria pertaining to biosolids application rate are discussed in section 2.3 (c). The application rate is usually expressed as tonnes of dry biosolids that can be applied to a hectare of land. It is critical that the biosolids spreading equipment is properly calibrated to achieve the specified application rate. The municipality that receives the Letter of Authorization is ultimately responsible to ensure compliance with the specified application rates.

Developing methods to ensure uniform application of biosolids is a key element in the land spreading program. For detailed information on acceptable spread patterns for manure spreaders, refer to The University of Georgia College of Agricultural & Environmental Sciences Cooperative Extension Services Information Brochure, "Calibration of Manure Spreaders".

A uniform application of biosolids requires no missed areas or double applied (overlapped) areas occur in a field. Eliminating missed or overlapped areas requires careful operation of application equipment. Equipment operators must know the amounts of biosolids distributed across the width of the spread swath in order to determine the amount of overlap that is required for the adjacent application. The operators must ensure that constant uniform spread patterns, discharge rates, speed, spreader revolutions, etc. are maintained. For subsurface injection applications, they must ensure that pressures are maintained at specified levels, and the injection nozzles are checked regularly to prevent plugging.

Biosolid waste is discharged from a tank using a pump, flail, spinner or deflector plate. Most systems rely on gravity to empty the load, which results in decreased discharge rate as the tank empties. Pump systems provide more uniform discharge, and is recommended.

The following method may be used to ensure uniform application of biosolids at the specified rate:

i) Convert the biosolids application rate, specified in the Letter of Authorization, from dry weight to wet weight [P tonnes per hectare]. (Note: One must know the concentration of the solids in the biosolids to do this step. Concentration of biosolids should be determined as per the procedure outlined for Total, Fixed and Volatile Solids in Solids and Semi Solid Samples as set out in the latest edition of the Standards Methods for examination of Water and Wastewater. Because of extreme variability in the biosolids concentration, repetitive sampling and analysis may be required.)

ii) Determine capacity [T in cubic meter] of the tank. Assuming density of biosolids equals 1 tonne per m^3, total weight of biosolids in the tank = T tonnes.

iii) Measure width [w in meter] of the spread swath/the path over which the biosolids are spread.

iv) Do a trial run at a constant uniform speed, and determine the distance [d in meter] the unit travels to empty the tank. (Note: This may be achieved by counting the wheel rotations or with an odometer).

v) Calculate on site application rate, $Q = \frac{T \times 10{,}000}{d \times w}$ tonnes per hectare.

vi) Compare 'P' and 'Q'. If not equal, do a second run with a different speed to increase or decrease 'd', as the case may be. The exercise should be continued till 'P' equals 'Q'.

Exceeding the specified application rate may expose the municipality to possible:

i) Action by AENV for non compliance of the Letter of Authorization;

ii) Farmer related liabilities arising from yield reductions, or grading differences suffered by crops grown on biosolids applied lands;

iii) Contamination of groundwater from the leachate; and

iv) Delay for repeat applications of biosolids.

Under application of biosolids may result in:

i) Increased disposal costs to the municipality, as a larger land base will be required; and

ii) inadequate amounts of nutrients to the crops.

4.0 PROCEDURE FOR OBTAINING AUTHORIZATION

Land treatment of biosolids is considered to be part of the operation of a wastewater system. The owner of the biosolids-producing facility must apply for authorization to spread biosolids to land in accordance with "Wastewater and Storm Drainage Regulation" (AR249/93), as amended.

The application form in Appendix B of this document must be completed and delivered to the appropriate Alberta Environment regional office. The applicant may also be requested to provide additional information to that requested on the form. A Regional Director for Alberta Environment's Environmental Service, or a designated representative, will assess the application and, if judged favourable, issue an authorization specifying conditions which must be adhered to in the land treatment scheme. Assessment of all proposals will be based primarily on the criteria listed in Tables 1 to 5 (Appendix A).

APPENDIX A

THE CRITERIA USED TO DIRECT LAND SPREADING OF BIOSOLID WASTES

TABLE 1.
Minimum Acceptable Ratios of Nitrogen and Phosphorus to Metals

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Nitrogen (Organic + Nitrate + Ammonium)	1,500	20	15	3,000	100	20	10
Or[1]							
Phosphorus (Total)	600	8.0	6.0	1,100	40	8.0	4.0

[1] Biosolids is unacceptable if either the nitrogen or phosphorus criterion is not met. Spiking biosolids with nitrogen or phosphorus to achieve these ratios is not permitted.

TABLE 2.
Classification of Sites on the Basis of Site and Soil Characteristics

	Acceptable[1]			Not Acceptable
	Class 1 Sites	Class 2 Sites	Class 3 Sites	Class 4 Sites
pH	≥ 6.5	≥ 6.5	≥ 6.5	< 6.5[2]
"Texture"[3]	CL, SiCL, SiL, Si, SiC, L, SCL, SC	C, HC	LS, SL	Sand and gravel[4]
Slope (%)[5]	0-2	2-5	5-9	9
Depth to Potable Aquifer (m)	> 5	3-5	2-3	< 2

[1] A site falls into the lowest class represented by any characteristic.
[2] A site with a pH less than 6.5, which would otherwise be classed 1, 2, or 3, may be upgraded by liming to pH 6.5 or higher.
[3] As determined on samples from representative soil horizons to a depth of at least 30 cm.
[4] Other class 4 sites include stream valleys, intermittent drainage areas and organic soils.
[5] Restriction of biosolids application rates based on slope considerations apply only when surface application methods are employed. Slope criteria can be relaxed if biosolid waste is applied by subsurface injection.

TABLE 3.
Maximum Addition of Solids and Nitrogen for Each Site Class and Biosolids Type - Single Application

Biosolids Type	Solids Application Rate[1]			Total Nitrogen Application Rate			Available Nitrogen $[(NH_4 + NO_3) - N]$ Application Rate for Surface Spreading[2]		
	t/ha dry weight basis			kg/ha			kg/ha		
	Class 1 Sites	Class 2 Sites	Class 3 Sites	Class 1 Sites	Class 2 Sites	Class 3 Sites	Class 1 Sites	Class 2 Sites	Class 3 Sites
Digested	25	20	10	900	700	400	450	350	200
Wastewater Lagoon	10	8	5	800	600	300	400	300	150
Undigested[3]	5	4	2.5	600	500	200	300	250	100

[1]For surface application a maximum hydraulic loading rate of 100 m^3/ha/day is imposed for biosolids containing less than 5% solids. Allowable solids and nitrogen rates for such biosolids may be achieved by making several incremental additions with the soil cultivated between each addition. There is no hydraulic loading rate restriction on sub-surface injection.

[2]For sub-surface injection the maximum available nitrogen application rate is 200 kg/ha on Class 1 and 2 Sites and 150 kg/ha on Class 3 Sites.

[3]Additional restrictions may apply to undigested sludge based on site specific conditions.

TABLE 4.
Maximum Cumulative Additions (kg/ha) of Biosolids-Borne Elements to Soil[1]

	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Class 1 Sites	1.5	100	200	0.5	25	100	300
Class 2 Sites	1.1	75	150	0.4	19	75	200
Class 3 Sites	0.8	50	100	0.2	12	50	150

[1] Not more than one-third of the cumulative loading may be applied in a single application.

TABLE 5.
Additional Application Restrictions

FEATURE	MINIMUM DISTANCE[1] (m)	
	Surface Application	Subsurface Injection
Rivers[2], Canals[2], Creeks[2], Intermittent Drainage Courses, Lakes, Sloughs, Dugouts	30	10
Water Wells	20	20
Areas Zoned Residential or Devoted to Urban Use	500	165
Occupied Dwellings	60	20
Public Building Perimeters	10	3
Public Buildings	60	20
School Yard Boundaries (School in Session - September to June, inclusive)	200	66
School Yard Boundaries (School not in Session - most of July and August)	20	7
Cemeteries, Playgrounds, Parks, Campgrounds	200	66

1. Greater separation distances may be required based on local topographic and climatic conditions.
2. Distances required are from the major break in slope.

1. Method of Application

Acceptable methods include injection and surface application. If surface application is employed it must be followed, as soon as possible, by tillage to incorporate biosolids with surface soil materials.

2. Minimum Acceptable Distances from Specified Features

The minimum setback distances in Table 5 apply when spreading biosolids to land. Municipalities and haulage contractors might, in an effort to enhance public acceptance of biosolids spreading programs, exceed these distances.

3. Seasonal

In general, spreading biosolids to land is permitted during spring, summer, and fall and is not permitted on ground which is ice-covered, snow-covered, or frozen. Exceptions might be made when there is a summer or fall snowfall or when unseasonal cold weather freezes the surface layer of soil. Regardless of the time of year, land spreading will be approved as long as incorporation of surface applied biosolids is possible.

4. Land Use

Acceptable Crops[1]	**Unacceptable Crops**
Forages[2]	Root crops
Oil seed crops	Fresh vegetables and fruits
Small grains[3]	Tobacco
Dried peas and beans	Dairy pasture land
Commercial sod	
Trees	

[1] Permission to apply biosolids on lands intended for growth of crops not listed may be given.

[2] Direct grazing of biosolids treated forage lands should be delayed for a minimum of three years following application.

[3] Wheat is preferable to barley, and it is better to schedule these crops early in the crop rotation after biosolids application. It is better to schedule oats later in the crop rotation, preferably at least two growing seasons following biosolids application.

5. Application of Biosolids to Previously Treated Land

In addition to the criteria listed above, three conditions must be met before re-application of biosolids to a particular site is permitted:

1) a minimum period of three years must have elapsed after the previous biosolids application event (local development authorities might extend this time period);

2) plant available nitrogen (NH_4-N and NO_3-N) in the surface 150 cm of soil shall be no greater than 250 kg/ha; and

3) the maximum cumulative additions of biosolids-borne elements shall not exceed the limits specified in Table 4.

APPENDIX B

APPLICATION FORM FOR AUTHORIZATION TO SPREAD BIOSOLIDS TO LAND

APPLICATION FOR PERMISSION TO SPREAD BIOSOLIDS TO LAND IN ALBERTA

Pursuant to Section 8 of the Environmental Protection and Enhancement Act, Regulation 119/93 written permission for land treatment of biosolids is required. Application for a "Letter of Authorization" must be made to the Regional Director by the owner of the facility producing the biosolids or his/her authorized agent. Completion of this form constitutes such an application. Completed forms accompanied by a map delineating the proposed disposal site should be sent to:

Alberta Environment
Northeast Boreal Region
Regional Director
6th Floor, 9820 - 106 Street
Edmonton, Alberta, T5K 2J6
Phone: (780)427-7617
Fax: (780)427-7824

Alberta Environment
Northern East Slopes Region
Regional Director
Provincial Building
#203, 111 - 54 Street
Edson, Alberta, T7E 1T2
Phone: (780)723-8357
Fax: (780)723-8386

Alberta Environment
Bow Region
Regional Director
201 Deerfoot Square
2938 - 11 Street, NE
Calgary, Alberta, T2E 7L7
Phone: (403)297-7948
Fax: (403)297-5944

Alberta Environment
Parkland Region
Regional Director
3rd Floor, 4920 51 Street
Red Deer, Alberta T4N 6K8
Phone: (403) 340-7744
Fax: (403) 340-5022

Alberta Environment
Northwest Boreal Region
Regional Director
2nd Floor, 9621 96 Avenue
Bag 900, Box #5
Peace River, Alberta T8S 1T4
Phone: (780) 624-6330
Fax: (780) 618-4350

Alberta Environment
Prairie Region
Regional Director
2nd Floor, 200 5 Avenue South
Lethbridge, Alberta T1J 4C7
Phone: (403) 381-5322
Fax: (403) 382-4428

Name, address and phone number of municipality:
____
____

Biosolids Type: Digested ____ Anaerobic ____ Aerobic ____
Wastewater lagoon ____ Undigested ____

Biosolids solids content ________ percent Volume of biosolids proposed for land treatment __________ cubic metres

Location of proposed application site: LSD ___ Section ___ Township ___ Range ___ W ___ Meridian

Has biosolids been applied to this site previously? No. ___________ Yes. ______ Specify dates ______________________

Proposed method of application: Injection ________________ Surface application and incorporation ___________

Name, address, and phone number of the haulage contractor
____
____

Does the proposed site meet all distance criteria in Table 6 of this document? _____ Yes ____ No

If no, specify which criteria are not met and by what distance
____
____

Current use of the proposed site: Fallow ________
Cropped ________ Specify ______________________________

Intended/Projected use of the proposed site over the next five growing seasons:

Year Fallow/Crop Type Year Fallow/Crop Type

Name, address, and phone number of the landowner:
____
____

Proposed date of commencement: ______________________________

Proposed date of termination: ______________________________

Signature of Mayor or authorized agent: ______________________________

Date: ______________________________

Landowner or individual(s) farming land receiving biosolids agree that root crops, vegetable and fruit crops and tobacco crops shall not be grown on biosolids amended lands and that said lands shall not be used for grazing of dairy cattle unless approvals to grow these crops or graze dairy cattle is obtained from Alberta Environment.

Signature of landowner ______________________________ Date ____________________

APPENDIX C

SKETCH MAP AND WORKSHEETS FOR BIOSOLID WASTE AND SITE ASSESSMENT

LAND TREATMENT OF MUNICIPAL BIOSOLIDS
FIELD INVESTIGATION REPORT

Legal land location: _____ _____ Tp _____ R _____ W _____
Investigation date: ____

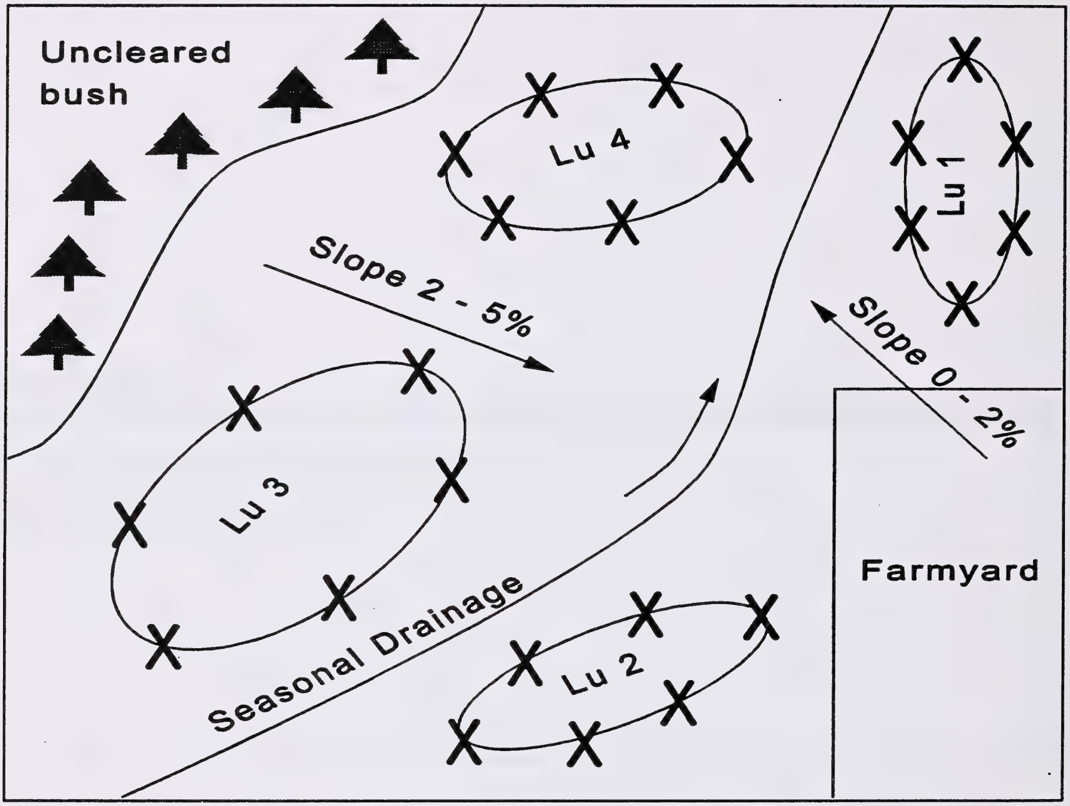
LU means land unit; X's indicate sampling locations

Proximity and direction to publicly used land features:

	Distance (metres)	Direction
Residential areas	__________	_______
Schools	__________	_______
Other farmyards	__________	_______
Parks, playgrounds	__________	_______
Others ____________________	__________	_______

LAND TREATMENT OF MUNICIPAL BIOSOLIDS
FIELD INVESTIGATION REPORT
(SAMPLE)

Legal land location: S x n SW 25p 7 4Rg 1 W 5M
Investigation date: ______________________



LU means land unit; X's indicate sampling locations

Proximity and direction to publicly used land features:

	Distance (metres)	Direction
Residential areas	none	______
Schools	none	______
Other farmyards	1 mile	north
Parks, playgrounds	350 m	south
Others MD waterwell	1/2 mile	east

MUNICIPAL BIOSOLIDS QUALITY REPORT

Community: ____________________________

Investigation date: ____________________________

Solids (%) ____________

Total nitrogen (%) ____________

Ammonium nitrogen (%) ____________

Total phosphorus (%) ____________

Metal	µg/g	Nitrogen/metal Ratio	Guide Min. (Table 1)	Phosphorus/metal Ratio	Guide Min. (Table 1)
Cadmium	_____	______________	1500	________________	600
Chromium	_____	______________	20	________________	8
Copper	_____	______________	15	________________	6
Lead	_____	______________	20	________________	8
Mercury	_____	______________	3000	________________	1100
Nickel	_____	______________	100	________________	40
Zinc	_____	______________	10	________________	4

$$\text{Nitrogen/Metal Ratio} = \frac{\text{Total N (\%)} \times 10000}{\text{metal } (\mu g/g)} \qquad \text{Phosphorus/metal ratio} = \frac{\text{Total P (\%)} \times 10000}{\text{metal } (\mu g/g)}$$

MUNICIPAL BIOSOLIDS
PARAMETERS LIMITING APPLICATION RATE
(tonnes dry solids/hectare)

	Class 1 Site				Class 2 Site				Class 3 Site			
	Digested		Lagoon		Digested		Lagoon		Digested		Lagoon	
Solids		25		10		20		8		10		5
Total nitrogen	1	___	11	___	21	___	31	___	41	___	51	___
NH_4-N (inject)	2	___	12	___	22	___	32	___	42	___	52	___
NH_4-N (surface)	3	___	13	___	23	___	33	___	43	___	53	___
Cd	4	___	14	___	24	___	34	___	44	___	54	___
Cr	5	___	15	___	25	___	35	___	45	___	55	___
Cu	6	___	16	___	26	___	36	___	46	___	56	___
Pb	7	___	17	___	27	___	37	___	47	___	57	___
Hg	8	___	18	___	28	___	38	___	48	___	58	___
Ni	9	___	19	___	29	___	39	___	49	___	59	___
Zn	10	___	20	___	30	___	40	___	50	___	60	___

Most limiting

	Class 1 Digested	Class 1 Lagoon	Class 2 Digested	Class 2 Lagoon	Class 3 Digested	Class 3 Lagoon
Rate (t/ha):	______	______	______	______	______	______
Parameter:	______	______	______	______	______	______

Calculation formulas (use with this form or in an electronic spreadsheet):

1	90/Total N(%)	11	80/Total N(%)	21	70/Total N(%)
2	20/NH_4-N(μg/g)	12	20/NH_4-N(μg/g)	22	20/NH_4-N(μg/g)
3	45/NH_4-N(μg/g)	13	40/NH_4-N(μg/g)	23	35/NH_4-N(μg/g)
4	1500/[3*Cd(μg/g)]	14	1500/[3*Cd(μg/g)]	24	1100/[3*Cd(μg/g)]
5	100000/[3*Cr(μg/g)]	15	100000/[3*Cr(μg/g)]	25	75000/[3*Cr(μg/g)]
6	200000/[3*Cu(μg/g)]	16	200000/[3*Cu(μg/g)]	26	150000/[3*Cu(μg/g)]
7	100000/[3*Pb(μg/g)]	17	100000/[3*Pb(μg/g)]	27	75000/[3*Pb(μg/g)]
8	500/[3*Hg(μg/g)]	18	500/[3*Hg(μg/g)]	28	400/[3*Hg(μg/g)]
9	25000/[3*Ni(μg/g)]	19	25000/[3*Ni(μg/g)]	29	19000/[3*Ni(μg/g)]
10	300000/[3*Zn(μg/g)]	20	300000/[3*Zn(μg/g)]	30	200000/[3*Zn(μg/g)]
31	60/Total N(%)	41	40/Total N(%)	51	30/Total N(%)
32	20/NH_4-N(μg/g)	42	15/NH_4-N(μg/g)	52	15/NH_4-N(μg/g)
33	30/NH_4-N(μg/g)	43	20/NH_4-N(μg/g)	53	15/NH_4-N(μg/g)
34	1100/[3*Cd(μg/g)]	44	800/[3*Cd(μg/g)]	54	800/[3*Cd(μg/g)]
35	75000/[3*Cr(μg/g)]	45	50000/[3*Cr(μg/g)]	55	50000/[3*Cr(μg/g)]
36	150000/[3*Cu(μg/g)]	46	100000/[3*Cu(μg/g)]	56	100000/[3*Cu(μg/g)]
37	75000/[3*Pb(μg/g)]	47	50000/[3*Pb(μg/g)]	57	50000/[3*Pb(μg/g)]
38	400/[3*Hg(μg/g)]	48	200/[3*Hg(μg/g)]	58	200/[3*Hg(μg/g)]
39	19000/[3*Ni(μg/g)]	49	12000/[3*Ni(μg/g)]	59	12000/[3*Ni(μg/g)]
40	200000/[3*Zn(μg/g)]	50	150000/[3*Zn(μg/g)]	60	150000/[3*Zn(μg/g)]